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NASA/JPL AIRBORNE THREE-FREQUENCY POLARIMETRIC/INTERFEROMETRIC SAR SYSTEM

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ABSTRACT

The NASA/JPL airborne SAR system (popularly known as "AIRSAR") has been flown aboard the NASA Ames Research Center DC-8 since 1987. AIRSAR is a three frequency (P-, L-, and C-bands) polarimetric radar with the interferometric capability. Even though various modes of operation are possible with the AIRSAR system, it has three basic operational modes (polarimetric, across track interferometry, and along track interferometry).

The AIRSAR hardware consists of RFE (RF Electronics), digital electronics, antenna, control computer, on-board processor, and power distribution subsystems. A single DCG (Digital Chirp Generator) generates the chirp waveform and it is up-converted to L-band. Subsequent up- and down- conversions produce C- and P- band chirp signals, respectively. The return echo is amplified by LNA (Low Noise Amplifier) and digitized by 8-bit ADC (Analog-to-Digital Converter). The digital data from six channels are multiplexed and stored on tape using the high density digital recorder.

During the AIRSAR mission, a real time correlator produces low resolution imagery to assess the general health of the radar and to verify that the correct area has been imaged. Data processing to produce high quality image products happens in the weeks and months following a flight campaign after proper calibration parameters are generated. The current integrated processor can process both polarimetric and interferometric data. In this talk, we will present detailed mission description, hardware configuration, and data processing

INTRODUCTION

The NASA/JPL airborne SAR (AIRSAR) system became operational in late 1987 and flew its first mission aboard a DC-8 aircraft operated by NASA's Ames Research Center in Mountain View, California. Since then, the AIRSAR has flown missions every year and acquired images in North, Central and South America, Europe and Australia.

The AIRSAR system can operate in the fully polarimetric mode at P-, L-, and C-band simultaneously, Both ATI (Along-Track Interferometry) and XTI (Cross-Track Interferometry) modes are available at L- and C-bands In the following sections, we will briefly describe the instrument characteristics and performance. In addition, we will discuss data processing and calibration of the radar.

INSTRUMENT CHARACTERISTICS

To achieve polarimetric capability, the AIRSAR system transmits the H- and V- polarized signals. Receive polarization diversity is accomplished by measuring six channels of raw data simultaneously, both H and V polarizations at all three frequencies. The video data are digitized using 8-bit ADCs, providing a dynamic range in excess of 40 dB. This raw data together with navigation data is stored on tape using high density digital recorders. The AIRSAR system also includes a real-time processor capable of processing any one of the 12 molar channels into a scrolling image. In addition to chc.eking the health of tbc radar, the set oiling display is also used to ensure that the correct area has been imaged. 'J'able 1 provides a summary of the AIRSAR system characteristics. AIRSAR can be operated in many different modes due to the complexity and flexibility of the instrument.

Parameter	Value
Chirp Bandwidth (MHz)	**20** (40)
Chirp Center Freq. (MHz)	P: 438.75 (42.7.5) L: 1248.75 (1237.5) C: 5298.75 (5287.5)
Peak Transmit Power (dBm)	P:62 L: 67 **c:** 60
Antenna Gain (dBi)	P: 14 L:18 C:24
Azimuth Beamwidth (deg)	P: **19.0** **L:** 8.0 C: 2.5
Elevation Beamwidth (deg)	P: 38.0 L: **44.0** C: **50.0**
ADC Sampling (MHz)	45 (90)
Data Rate (MB/s)	10
NE σ_0 (dB)	P: -45 L: -4s C: -35
Nominal Altitude (m)	8000
Nominal Velocity (Knots)	450
Slant Range Resolution (m)	10 (5)
Azimuth Resolution (m)	1
Ground swath	10-15

Table 1. Summary of AIRSAR system characteristics. The parameters in ( ) apply to 40 MHz chirp bandwidth configuration.

In addition to three frequency polarimetric mode, both ATI and XTI modes are available. ATI mode was successfully used to image ocean currents and waves moving in the radar line-of-sight direction. With addition of more antennas and antenna switching networks, AIRSAR is capable of taking XTI data (known as TOPSAR). TOPSAR was successfully used to generate topographic maps of areas of interest. Since 1995, wc have been experimenting with alternating the transmit antenna between the top and the bottom antennas (known as ping-pong mode). This effectively doubled the baseline and initial data analysis showed that the longer baseline produced DEMs (Digital Elevation Models) with reduced RMS height error as expected. In addition, the newly added L-band XTI mode produced DEMs of slightly higher RMS height error due to shorter baseline length (scaled by wavelength) compared with those of C-band XTI mode.

To produce accurate DEMs, wc need to know the baseline precisely. To do this, wc have also upgraded the Inertial Navigation System (INS) and the Global Positioning System (GPS) receiver in order 10 acquire more accurate knowledge of the location and attitude of the antennas. The original navigation system of AIRSAR consisted of a Honeywell INS with a ring laser gyro that determined the attitude of the aircraft and a Motorola Eagle 4-channel GPS receiver that provided the positioning information (latitude and longitude) of the aircraft. As technology advanced and our need for more accurate positioning and attitude information became more stringent, wc purchased a new Motorola Six-Gun GPS receiver and a new Honeywell Integrated GPS and INS (IGI) in 1994. The Six-Gun GPS receiver has six channels and a much more stable clock compared to the old unit and provides positioning accuracy of 100 m using CA code. This receiver was integrated in the radar in 1994. The Honeywell IGI has a smaller and more sensitive ring laser gyro integrated with a GPS receiver capable of receiving the more accurate but restricted Precise Positioning Service (PPS) data. The specifications on this unit are: 0.02' heading accuracy, 0.01° roll and pitch accuracy, 0.03 m/s velocity accuracy per axis, and 16 m positioning, accuracy with PPS. The IGI was installed on the DC-8 in 1994 but the data were recorded off-line and were not available in the radar header until the 1995 flight season. in addition, wc have also experimented with differential GPS by using a Turbo Rogue GPS receiver on the aircraft in conjunction with another Turbo Rogue receiver on the ground to obtain positioning accuracy of better than 1 m.

DATA PROCESSING

A variety of processor-s and processing techniques are utilized to process AIRSAR data to imagery. A real-time correlator is part of the AIRSAR radar flight equipment (the. Aircraft Flight Correlator) and is used to produce **low** resolution (approx. 25 meter) two look survey imagery. The same on-board equipment is used to generate a slightly higher resolution (1 5 meter), 16 took image of a smaller area (12 km x 7 km) within 10 minutes of acquisition using the quick-took processor. These on-board processors arc useful for assessing the general health of the radar and the success of data taking in real-tirne.

Final processing of selected portions of the data to high quality, fully calibrated image products happens in the weeks and months following a flight campaign. Currently, users may request images from two different operational processors, the synoptic processor and the frame processor. In the synoptic processor, the user specifies three data channels to be processed. About five minutes of raw data from each of the three selected channels arc processed to 16 looks and amplitude-only image strips, covering about 40 km along track. In 40 MHz mode, the image strips would be 8 looks and 20 km long. These image strips cover about 9 km in the slant range direction for the 20 MHz mode and 4.5 km for the 40 MHz mode.

in terms of frame processing, wc currently support two processor versions: the AIRSAR processor and the new integrated processor which is still under development. The new integrated processor was developed mainly to process XTI data since XTI mode has become increasingly popular.

In order to do so, we needed a new processor that tracks and compensates for the motion of the aircraft since uncorrected motion translates into baseline error between the two antennas, which results in height error in the DEM.

The integrated processor processes one minute of raw data of all available data channels into absolutely calibrated images in compressed Stokes matrix format that contains all the polarization information. If C-band cross-track interferometer data are available for the data take, the integrated processor will generate a digital elevation model and a local incidence angle map. By using the local incidence angle map, all output images will be geometrically and radiometrically corrected taking the topography into account and resampled to ground range with a 10 m by 10 m pixel spacing. The output images cover about 10 km in the range direction by about 10 km in the along-track direction for the 40 MHz mode, and about 20 km in the range direction by about 10 km in the along-track direction for the 20 MHz mode. Although the radar data rate allows us to image about 20 km in range swath for the 20 MHz mode, the increasing phase noise due to decreasing SNR as a function of incidence angle reduces the correlation between the two antenna channels. As a result, the RMS height error can be quite large in far swath due to poor SNR.

DATA CALIBRATION

The calibration of polarimetric data is well understood. Briefly, with the calibration tone in the receive chain and corner reflector verification, we are able to consistently produce polarimetric images with better than 3 dB absolute accuracy, better than 1.5 dB relative accuracy amongst the 3 radar frequencies, and better than 0.5 dB between the polarization channels. The relative phase calibration between the HH and VV channels is better than 10°.

The calibration of XTI data is much more challenging because various parameters, such as baseline vector, are involved in the XTI data processing. The absolute phase must be known in order to derive height information from the interferometric data without 2π ambiguity. The differential phase (between two channels) of the radar can be a function of system temperature. Therefore, we need to determine both absolute and differential phase for each data take. In addition, accurate knowledge of the baseline between the two antennas is necessary to generate accurate DEMs Using the Rosamond Dry Lake data, we are currently working on calibration of XTI data. In addition to usual calibration, we implemented the phase screen to remove systematic range dependent height errors which can be caused by multipath.

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